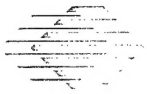

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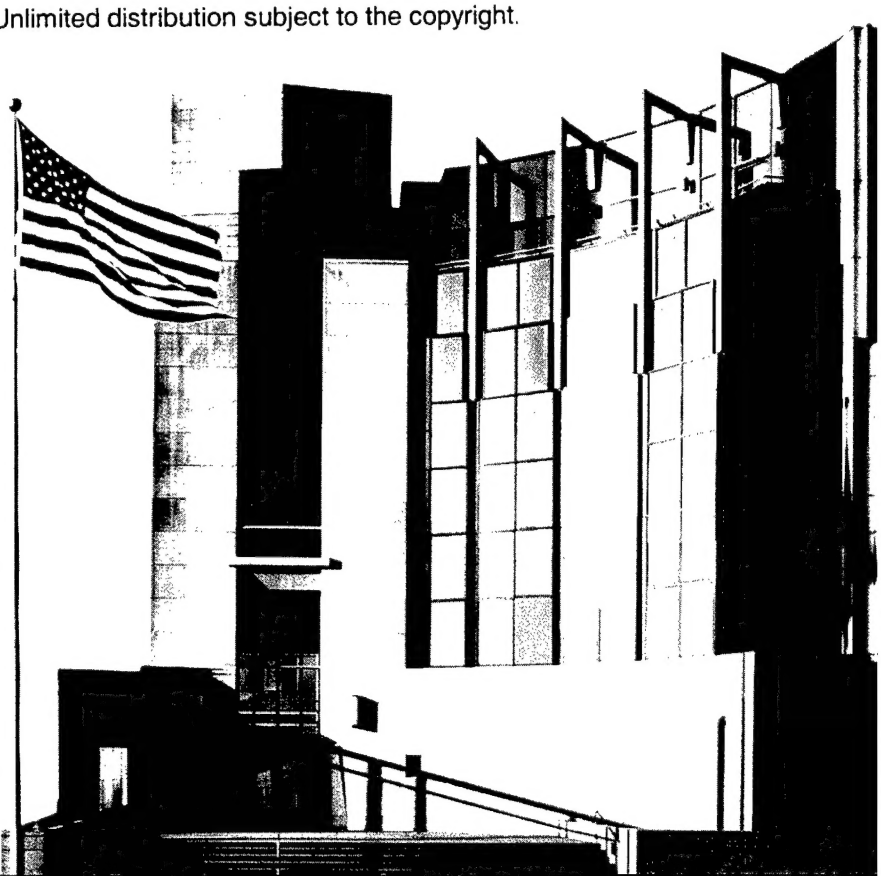
Using Quality Attribute Workshops to Evaluate Architectural Design Approaches in a Major System Acquisition: A Case Study

John Bergey
Mario Barbacci
William Wood

July 2000

Architecture Tradeoff Analysis Initiative



Technical Note
CMU/SEI-2000-TN-010

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Acknowledgements

We want to acknowledge the work of fellow team members Charles Weinstock and Robert Ellison in planning, developing, and executing the Quality Attribute Workshops on which this case study is based.

About the Technical Note Series on Architecture Evaluation in the Department of Defense

The Product Line Systems Program is publishing a series of technical notes to condense knowledge about architecture evaluation practices into a concise and usable form for the Department of Defense (DoD) acquisition manager and practitioner. This series is a companion to the Software Engineering Institute (SEI) series on product line acquisition and business practices [Bergey 99].

Each technical note will focus on architecture evaluations and in particular on the Architecture Tradeoff Analysis Method[SM] (ATAM[SM]) and related technology of the SEI. Our objective is to help the DoD integrate sound architecture evaluation practices into its acquisitions. This series of technical notes will lay a conceptual foundation for DoD architecture evaluation practice.

[SM] Architecture Tradeoff Analysis Method and ATAM are service marks of Carnegie Mellon University.

Abstract

To a large extent, a system's software architecture determines the quality attributes of both the software and the entire system. It is also one of the earliest artifacts available for evaluation. For a Department of Defense (DoD) or government acquisition organization, the ability to evaluate software architectures early in the acquisition cycle can positively affect the delivered system. To assist a government organization in evaluating architectures, a series of Quality Attribute Workshops (QAWs) were planned and an initial set conducted as part of a competitive acquisition of a complex, integrated command and control system. The QAW is a "lightweight" (i.e., non-intrusive) version of the Architecture Tradeoff Analysis Method[SM] (ATAM[SM]) developed by the Software Engineering Institute (SEI).

The QAWs provided the acquiring government agency with a means to evaluate each contractor's software architectural approach and determine whether it satisfied the system's quality attribute requirements (e.g., performance, interoperability, security). Since the acquisition is ongoing, follow-on workshops are currently being scheduled to evaluate the architectural designs as they evolve.

This technical note provides an overview of the QAW process and the results of the first set of workshops, including the perceived benefits of the workshops to both the acquirer and the contractors. It also discusses future opportunities for applying a full-scale architecture evaluation (e.g., an ATAM evaluation) in early stages of system acquisition, and identifies the benefits that could be obtained.

[SM] Architecture Tradeoff Analysis Method and ATAM are service marks of Carnegie Mellon University.

1 Introduction

Modern defense and tactical systems rely heavily on software to deliver functionality and operational capabilities.

The software architecture of these systems is key to achieving—or failing to achieve—their quality attribute goals. The ability to evaluate software architectures can help ensure that the delivered systems will meet these goals.

This technical note describes a series of Quality Attribute Workshops (QAWs) that are being conducted on behalf of a government agency during its competitive acquisition of a complex, tactical, integrated command and control system. The workshops are enabling the acquiring government agency to better understand each contractor's proposed software design approach. The workshops are also allowing the agency to evaluate the contractors' architecture development efforts very early in the acquisition cycle.

This technical note provides background information on the acquisition program, including the type of system being acquired and the acquisition context for conducting the workshops. Next, it describes the importance of architecture evaluation in system acquisition and its relationship to a QAW. It then conveys the motivation for a QAW, describes how the workshops are being conducted, and shows the perceived benefits to the acquiring agency and the participating contractors. Finally, the technical note describes how architecture evaluations could be applied in later phases of the acquisition process.

2 System Acquisition Context

2.1 The Acquisition Organization and the System Being Acquired

This case study describes an ongoing acquisition. The identities of the participants have been disguised to protect the privacy of all those involved. The acquiring government agency is referred to as the "AGA" and the system being acquired as the "TIC" system—an elaborate and sophisticated, tactical integrated command, control, and communication system.

Figure 1 shows the TIC system concept. It is a true "system of systems." It includes multiple ground, air, sea, and space assets for conducting a prescribed set of missions in different localities.

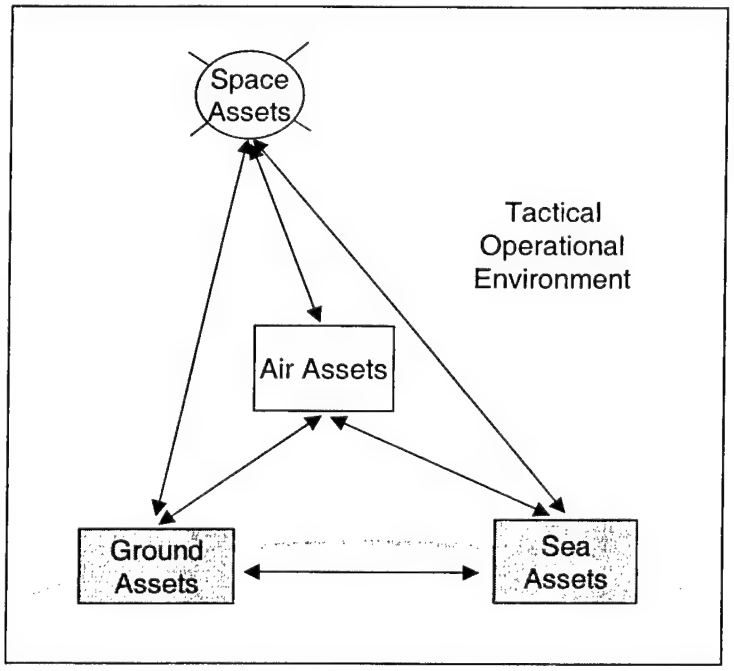

Figure 1: Conceptual Overview of the TIC System

The TIC system must concurrently support missions involving different asset combinations in predictable (and unpredictable) tactical situations and environmental conditions. As a result, the contractual system specification includes quality attribute requirements (e.g., security, interoperability, performance) that reflect this advanced system's capabilities. Of course, the logistical requirements must also be considered. The AGA faced the challenge of evaluating a contractor's proposed design to see if it provided the required quality attributes.

2.2 The Acquisition Strategy

Since a huge investment in time and resources was involved, the AGA adopted a two-phase acquisition strategy (shown in Figure 2) with a "rolling down-select"[1] to maximize competition and reduce risk.

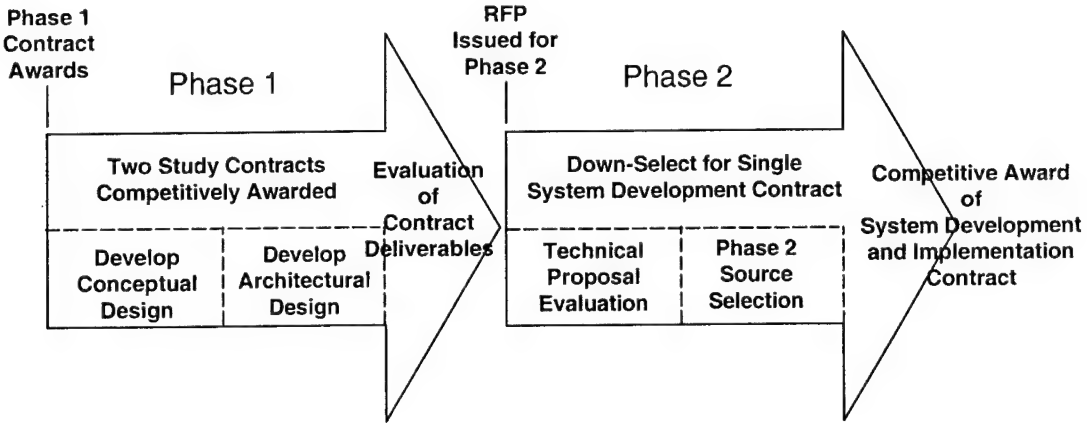

Figure 2: Two-Phase System Acquisition Strategy

In Phase 1, the agency competitively awarded two contractors fixed-price study contracts to define their systems at a very high level. The Phase 1 study contract, which is currently ongoing, calls for each contractor to develop a conceptual design for the system followed by an architectural design. In parallel with the architectural design, the contractor must also develop a Concept of Operations (CONOPS) for the TIC system. The study contract enables both contractors to refine their system concepts and architectures so that they can estimate system development costs and schedules with known (and acceptable) risk. At the time the first set of workshops was conducted, both contractors had completed their conceptual designs and were developing their architectural designs.

The contractors were not scheduled to complete their architectural designs and formally deliver them to the AGA until the end of the second half of Phase 1. The study contracts specify that the contractors must develop their architectures in accordance with the Department of Defense's Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Architecture Framework[2] [AWG 98]. As a result, each contractor must deliver C4ISR operational, systems, and technical architecture

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[1] A "rolling down-select" refers to an acquisition strategy where relatively short-term contracts are initially awarded to multiple contractors followed by another Request for Proposal (RFP) to competitively award a single contract (to complete the work) to the contractor submitting the "best value" proposal.

[2] This framework is becoming the required method for describing information systems architectures within the DoD and other U.S. government agencies.

descriptions[3] for their proposed systems. Seven C4ISR operational views define operations from asset and user perspectives. Eleven C4ISR systems products define the organization of hardware and software components. Two C4ISR technical products identify the standards and commercial products in the system, forecast their evolution, and describe the inclusion of emerging standards and commercial products.

Integrated Project Teams (IPTs) are currently evaluating the Phase 1 deliverables to determine whether they meet the contractual requirements. The IPTs are also assessing the strengths, weaknesses, and risks of each contractor's proposed approach. A separate Architecture IPT is evaluating each contractor's proposed architecture. Among other requirements, the Phase 1 contract specifically states that the TIC system must satisfy five system quality attributes: performance, availability, security, interoperability, and modifiability.

Once the Phase 1 study contracts are complete, the AGA will begin Phase 2 and issue a Request for Proposal (RFP). The AGA team will then formally evaluate the contractors' Phase 2 proposals. A source-selection team will make a "down-select" and award the TIC system development and implementation contract to the organization whose proposal represents the "best value" to the government.

[3] An SEI Technical Report (CMU/SEI-99-TR-014) "*Architecture Tradeoff Analyses of C4ISR Products*" describes how C4ISR products can be used for generating quality attribute-specific scenarios in the context of an ATAM evaluation. [Barbacci 99]

3 Role of Architecture Evaluation in System Acquisition

Software architecture is important because it embodies the decisions and tradeoffs made during the earliest, high-level design stages. These design decisions will drive the entire software development effort and ultimately determine software quality. These decisions are the hardest to get right. They have the farthest-reaching repercussions on the system's operation, capabilities, and qualities. These decisions are also the hardest to change downstream. If an inappropriate architectural choice is made, the impact is profound. Studies show that fixing an error during requirements or early design phases costs orders of magnitude less than fixing the same error found during testing [Boehm 81]. Thus, it makes sense to evaluate the software architecture of a system as early as possible.

For example, if a system has stringent real-time performance requirements, the architect must pay attention to inter-component communication and intra-component deadlines. If there are modifiability goals, the architect must pay attention to the encapsulation properties of components. If reliability is important, the architect must pay attention to redundant components. The list goes on. In each case, the quality attribute can be traced back to the decomposition of the total system into parts and the ways in which those parts communicate and cooperate with each other. While a "good" architecture cannot guarantee a successful implementation (i.e., the system meets its quality goals), a "bad" architecture can certainly preclude one.

Ideally, risk mitigation should begin during architecture definition and refinement. An architecture evaluation[4] is one risk mitigation activity that has been shown to have a high payoff. While conducting an architecture evaluation may appear to be an obvious step, it certainly isn't a routine occurrence, especially in DoD and government organizations that greatly depend on acquisition practices.

The Architecture Tradeoff Analysis Method (ATAM) is a technique for analyzing a software architecture with respect to the quality attributes of the system. The technical staff at the SEI have developed and refined this method over the past three years [Kazman 00]. The ATAM can detect areas of potential risk within the architecture of a complex software–intensive system. It reveals how well an architecture satisfies goals and provides insight into how these quality goals interact with each other. It also allows engineering tradeoffs to be made among possibly conflicting quality goals.

[4] This is distinguished from an architectural review that is a typical part of an acquisition milestone such as a Critical Design Review.

The ATAM evaluation can be applied early in the software-development life cycle. It can be performed quickly and inexpensively. And it does not require detailed analyses of measurable quality attributes, such as mean time to failure or latency, to succeed.

Members of the SEI technical staff have used ATAM to evaluate the software architectures of systems at various phases in their life cycles:

- before architectural decisions have been completely determined
- after architectural decisions have been determined, but before detailed design and coding activities have started or have been completed
- after system deployment, when modernization is being considered
- before system development, when multiple candidate architectures are being considered

A complete description of the ATAM method is found in *ATAM: Method for Architecture Evaluation* [Kazman 00]. Currently, there are no generally accepted industry–wide standards for describing an architecture. Therefore, ATAM evaluations are often tailored to the available documentation.

4 The Quality Attribute Workshop (QAW)

In essence, a QAW is a "lightweight" or less intrusive version of an ATAM evaluation. Like an ATAM evaluation, it does not aim at an absolute measure of architectural quality. Rather, the objective is to identify

- scenarios from the point of view of a diverse group of stakeholders
- quality attribute sensitivity points, tradeoffs, and risks
- possible mitigation strategies

In a QAW, the actual analysis burden falls on the contractors, with the SEI facilitating the review of the analysis. Stakeholders typically include architects, developers, managers, sponsor representatives, systems and software engineers, logistics personnel, end users, and others who have a vested interest in the system.

In conducting a QAW, the workshop facilitators depend on a variety of inputs including stakeholder points of view, architecture documentation, and architectural designs. The contractor is responsible for supplying this information. Prior to a workshop, the participants receive a QAW handbook, similar to the *Quality Attribute Workshop Participants Handbook* [Barbacci 01]. It describes QAW activities and the facilitation tools that will be used. The workshops are typically one and a half days in length.

The QAW process is used to discover and document quality attribute risks, sensitivity points, and tradeoffs, where

- Quality attribute risks are architectural decisions that might create future problems for some quality attribute requirement.
- Sensitivity points are architectural parameters for which a slight change makes a significant difference in some quality attribute.
- Tradeoffs are architectural parameters affecting more than one quality attribute.

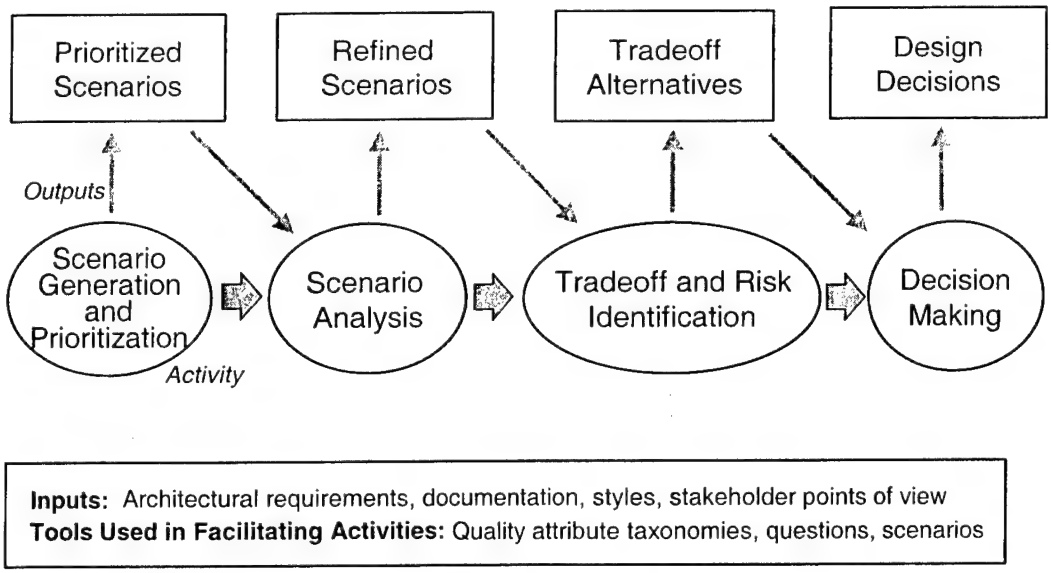

Figure 3: Roadmap of Activities for Quality Attribute Workshop

As shown in Figure 3, the QAW process consists of four major activities: (1) Scenario Generation and Prioritization, (2) Scenario Analysis, (3) Tradeoff and Risk Identification, and (4) Decision Making.

Scenario Generation occurs during a facilitated brainstorming process. Stakeholders propose scenarios that test the effectiveness of the contractor's proposed C4ISR architecture[5] to achieve specific quality attributes within a specific mission and geographic context. These scenarios are candidates for use in exercising the architecture against current and future situations. In general, there are three types of scenarios: (1) use-case scenarios, (2) growth scenarios, and (3) exploratory scenarios.

In the Prioritization activity, stakeholders are assigned a number of votes that they can allocate. The five or six scenarios garnering the most votes are selected for further analysis.

During the Scenario Analysis, stakeholders choose an appropriate architectural style or architecture fragment, and apply the scenario to the artifact. This analysis is designed to identify important architectural decisions and sensitivity points. As a result of this activity, the stakeholders might decide to conduct additional, more detailed or formal analyses of the scenarios or artifacts. These activities take place offline, not during the workshop.

During Tradeoff and Risk Identification, stakeholders use the results of the analysis to identify and document risks (i.e., potential future problems that might impact cost, schedule, or quality attributes of the system).

[5] From the perspective of the Architecture IPT, the systems and technical levels of the C4ISR architecture are the primary focus of the workshops; the operational level is viewed as setting the context and background that bounds the scope of the architecture evaluation.

During this phase, fruitful scenarios to consider include

- a single scenario that involves two quality attributes explicitly or implicitly
- multiple scenarios about different quality attributes sharing common factors (e.g., resources, protocols)
- multiple conflicting scenarios

In the final activity, Decision Making, contractor management adjudicates the tradeoffs and risks. These decisions are typically guided by contract requirements and system deliverables, including the prescribed quality attributes, the proposed system concept of operations, and the contractor's business goals and interests. Other upper-level managers may be brought in and advised of high-visibility alternatives and the corresponding impact of changes. This information is often sent to the sponsor as well.

QAWs enable an organization to generate and analyze scenarios about a system that is still in the process of being defined. This does not obviate the need, however, for something concrete to analyze. For example, if a scenario suggests that message throughput is important, QAW team members need a sketch of the components and connections that implement the subsystem that processes the messages. Since the workshop team members don't expect such decisions to have been made when they analyze a scenario, the architect can suggest the reasonable or likely candidate architecture for purposes of the exercise. The stakeholders are not bound to that solution and are not "graded" on the effectiveness of a choice made on the spur of the moment. The scenarios, screening and exploratory questions, and attribute tables remain with the organization, and the developers can repeat the exercise using alternative subsystem architectures.

5 Motivation for Conducting a QAW

In the case under discussion, the AGA did not have an effective means for evaluating whether a contractor's proposed design provided the required system quality attributes. Additionally, there were no contractual provisions to permit the AGA to conduct a formal architecture evaluation. Instead, the two contractors were only required to deliver documentation describing their C4ISR architectures. Moreover, conducting an ATAM evaluation at this juncture was considered inappropriate because the contractors were just developing their architectures and were not prepared for a formal evaluation.

As a result, the AGA tasked an SEI team to develop and conduct a series of incremental QAWs under the purview of the Architecture IPT. The goal of the workshops was to provide a suitable forum for discussing and evaluating quality attributes.

Plans for the QAWs included conducting three workshops at each contractor's site. The workshops were scheduled during the architectural design portion of the Phase 1 study contracts, prior to the Phase 2 "rolling down-select." Figure 4 shows the workshop schedule relative to the overall system acquisition cycle.

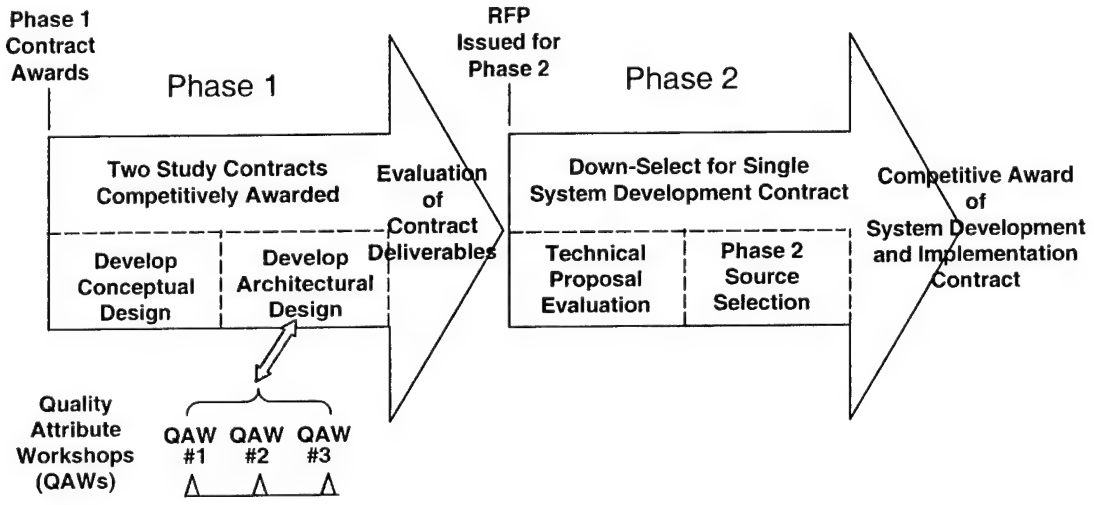

Figure 4: Scheduled Phasing of Quality Attribute Workshops

The AGA's overall objectives for the first set of QAWs were to

- gain a better understanding of each contractor's conceptual design and proposed architecture and its ability to provide the system quality attributes
- introduce contractors to the technology available for evaluating architectural representations
- enable participating contractors to gain insight into AGA issues and priorities
- provide a common basis for continued and closer dialogue during the study phase

5.1 Ground Rules Adopted for Conducting the Workshops

Although the AGA encouraged the contractors to participate in these QAWs, their participation was strictly voluntary. Prior to conducting each workshop at the contractor's site, AGA representatives made it clear that

- Participation is not a contractual requirement.
- Each contractor may decide whether to continue and how.
- All attendees are either contractor representatives or AGA and SEI representatives who have signed a Non-Disclosure Agreement (NDA).
- The initial workshop approach will be the same for both contractors, but follow-up sessions will be tailored per their desires.
- The QAWs will focus on the architecture evaluation process.

The SEI team codified the technology and facilitated the workshops under the sponsorship of the Architecture IPT.

Although the QAWs were, and still are, being conducted concurrently with the technical assessment of Phase 1 deliverables, the two efforts remain separate in keeping with the ground rules of the workshops.

6 Workshop Results and QAW Lessons Learned

With the voluntary cooperation of the contractors, good things happened in the first set of workshops. The workshops enabled the AGA to establish a proactive means of working with the contractors to conduct architecture evaluations in the early stages of system design. And the results established a solid "analysis baseline" that the AGA and the contractors can build on in future workshops to fully evaluate the architectures' inherent quality attribute sensitivities, tradeoffs, and risks.

Although it was not practical to complete all the roadmap activities, the QAW team did successfully generate a set of scenarios, prioritize them, and conduct a cursory analysis of the six top-priority scenarios. The QAW team did not perform the Tradeoff and Risk Identification Activity, however, due to a lack of time and system definition. Instead, team members evaluated the top-ranked scenarios and identified likely attribute tradeoffs and sensitivity points. From the standpoint of the AGA, the bottom line was that all parties gained from the workshops.

From the AGA's perspective, the workshops enabled it to

- have an informal, but structured information exchange that helped clarify the contractors' approach to satisfying the system requirements and quality attributes
- have a more substantive dialogue about the contractors' proposed operational concepts and C4ISR architectural issues
- understand the scenarios of concern to the contractors and the issues and implications associated with those scenarios
- identify and address stakeholders' concerns and the degree to which stakeholders and contractors shared a common view of how the system operates
- develop a set of high-priority scenarios to explore the quality attributes of its proposed system
- examine some of the contractors' decision-making processes and evaluate their ability to articulate their conceptual designs and C4ISR architectures

It became apparent during the workshops that the contractors, in general, were still wrestling with their operational concepts of how the TIC system would function and operate with the spectrum of AGA ground, air, space, and sea assets. In one case, it was obvious that the workshop represented the first time that all the stakeholders were "on the same page" about operational issues. There were also instances of the operational concept being refined "on the fly."

From the contractors' perspective, the workshops created a greater awareness of

- misunderstandings among the various stakeholders, operational issues that remain to be resolved, and design decisions that must be revisited
- the need to work on communication among project personnel
- the value of using scenarios to exercise the system, drive it down to the architectural level, and determine its impact on the system's quality attributes
- the need to capture issues and concerns that were particularly important to the AGA and the architecture IPT and to identify where there was a lack of understanding on their part

As a result, the AGA is planning follow-on workshops to help the Architecture IPT gain a better understanding of the systems being proposed. The second set of workshops will refine and apply scenarios generated by the AGA to evaluate the preliminary architectures of the competing contractors. The last set of workshops will evaluate each contractor's final architecture using scenarios selected by the AGA.

The QAW team members from the SEI expect that communication between all parties will improve in subsequent workshops. The contractors were reluctant to disclose some details of their system designs. They appeared leery of the workshops and possibly needed some workshop experience before revealing their proposed designs. This may have been due, in part, to the "high stakes" environment created by this very competitive acquisition. Other factors limiting communication may have been that their operational concepts were still evolving, and that their architectures were in very tentative stages of development. (Contractually, they were not scheduled to make a delivery for several months.)

In addition, the QAW team members from the SEI learned that they could not cover all four roadmap activities in a single workshop. They also learned that the examples in the workshop handbook were too detailed.

6.1 Acquisition Issues Related to Architecture Evaluation

One pertinent acquisition issue arose concerning the ground rules. Since the workshops were "advertised" as voluntary and informal interchanges, it followed that information or results derived from the QAWs should not be used in the formal technical assessment of the Phase 1 architecture, or in the Phase 2 technical evaluation and source-selection process. Without the authorization of the Contracting Officer or the Contracting Officer's Technical Representative (COTR), any formal use of the data could result in a protest and place the acquisition in jeopardy. This situation can be avoided by proactively specifying in the contract that workshops must be conducted as formal risk-mitigation checkpoints.

Another acquisition issue concerned the relationship of the Phase 1 architecture deliverables to the Phase 2 contract. Unless this relationship is clearly defined, the Phase 1 and Phase 2 contractual efforts may not be seamless. Since Phase 2 has many of the characteristics of an

independent acquisition, a contractor could submit a final proposal that is based on a new or modified conceptual design and architecture. In fact, this may be positive since the changes may have been incorporated to reduce the cost and time needed, and to mitigate risks discovered during Phase 1. This gives rise, though, to several thorny questions:

- How will the results of the IPT evaluation of the Phase 1 architecture be used in the Phase 2 source selection if the contractor's Phase 2 technical proposal affects the architecture proposed in Phase 1?
- How will Phase 2 proposals be evaluated comparatively if one of the contractors significantly changes its proposed Phase 1 architecture and another does not?
- Will there be sufficient time and resources, and an effective means to evaluate any changes that affect the architecture?

One potential remedy is a requirement in the Phase 2 RFP that each contractor identify the relationship of Phase 1 deliverables to its proposed technical approach for Phase 2. If the proposed approach for Phase 2 differs in any way, the contractor should describe the scope, nature, extent, and impact of any changes that affect the architecture. Another possible remedy is to perform an architecture evaluation as part of the Phase 2 source-selection process or system-development process.

The general underlying lesson learned is that it is always best to "plan early" to incorporate architecture evaluations in a system acquisition. This also applies to downstream opportunities to incorporate architecture evaluations in Phase 2. Several of those opportunities are described in the next section.

7 Downstream Opportunities for Conducting Architecture Evaluations

One question worth considering is where would formal[6] architecture evaluations have the greatest benefit? Since an inappropriate architectural choice can have such a profound impact, it makes sense to evaluate the architecture at critical points throughout the system's acquisition.

In particular, there are two downstream opportunities in Phase 2 where conducting an architecture evaluation can potentially achieve a high payoff. These two points of opportunity correspond to the technical proposal evaluation prior to contract award and early in the system development cycle. They are depicted in Figure 5 below.

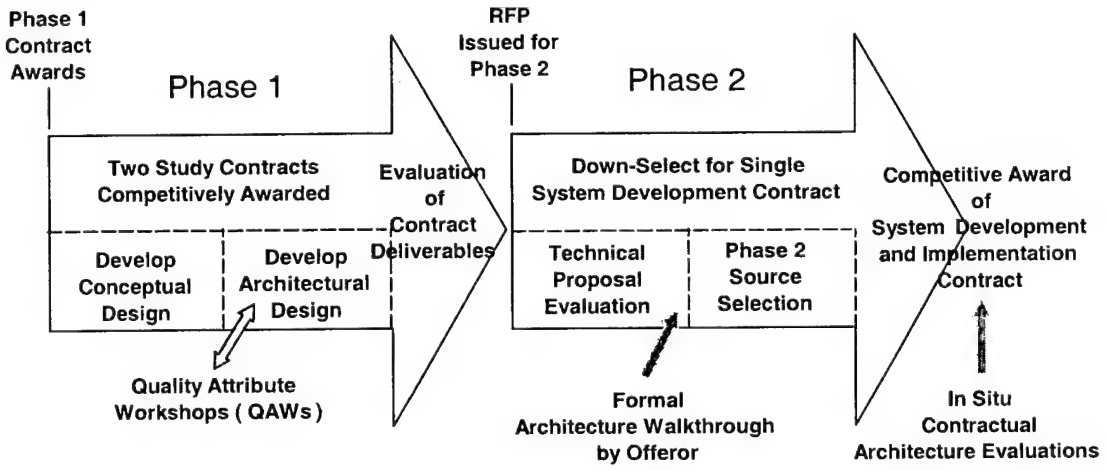

Figure 5: Key Acquisition Points for Conducting Downstream Architecture Evaluations

The next sections describe the two potential opportunities in detail.

[6] It is formal in the sense that it is a contractual requirement.

7.1 Formal Architecture Walkthrough and Evaluation as an Element of Technical Proposal Evaluation and Source Selection

We recommend that each contractor prepare an architecture walkthrough and evaluation as part of its technical proposal presentation (in accordance with guidelines supplied by the AGA in the RFP). In the walkthrough and evaluation, each competing contractor would present its proposed architecture and show how it satisfies the system's quality attribute requirements for a prescribed set of scenarios. This can be an effective means of evaluating a proposed software architecture and comparing one approach with another.

Bernhardt describes using such a walkthrough and evaluation as part of the source selection process for a major DoD system acquisition [Bernhardt 00]. In this example, the architecture evaluation results were used to select the best value among the proposed architectures. This involves including the appropriate language[7] in the *Instructions to Offerors* and in Section M of the RFP that describes the *Evaluation Factors for Award.*

Should the AGA elect to require an architecture walkthrough and evaluation in Phase 2, it should consider building on the QAW results. As the first step in this strategy, the AGA should prepare and issue a set of 20 to 40 representative scenarios[8] to both the contractors far in advance of issuing the RFP for Phase 2. These candidate scenarios would include normal, adverse, and growth situations that reflect the high priority mission needs and quality attribute requirements of the AGA.

Coinciding with the submission of the contractors' written technical proposals, the AGA would select a small number of scenarios from this larger group and inform the contractors which ones were selected. It would require each contractor to conduct a formal architecture walkthrough and evaluation using this smaller set of scenarios[9] as part of its technical proposal presentation. This strategy forces a contractor to consider all 20 to 40 scenarios in order to fully prepare for the required architecture walkthrough and evaluation that will occur during technical proposal evaluation.

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[7] This topic will be covered in a future technical note.

[8] The number of scenarios would depend, in part, on the complexity of the system.

[9] If the scenario evaluation were commensurate with the QAW approach, a practical limit on the number of scenarios would be four.

7.2 Conducting In Situ Architecture Evaluations During System Development

Once a contract has been awarded, we recommend performing an in-depth architecture evaluation (e.g., an ATAM evaluation). An architecture evaluation can help the acquiring organization

- select an architecture among several candidate architectures
- evaluate architecture designs to reduce program risks
- refine a design once an architecture has been chosen

Bergey describes using in situ software architecture evaluations as contractual checkpoints in system acquisitions [Bergey 99]. These evaluations enable architects to address risks when costs and effort for later rework can be minimized. The contractor in cooperation with the acquiring organization performs the software architecture evaluations. This is consistent with the spirit of acquisition reform, because the contractor is not told *how* to develop the system, only *what* qualities it must deliver in the system. It also provides the government with an effective means of evaluating system quality and reducing risk. Although this technical note refers to the Architecture Tradeoff Analysis Method for such evaluations, any evaluation method that focuses on quality attributes could be used.

Using architecture evaluations as contractual checkpoints would enable the AGA to monitor and evaluate the winning contractor's proposed Phase 2 architecture[10] early in the system-development cycle. This could prevent major design problems from rippling through the entire software development effort. Again, these evaluations could also help the AGA to explore other potential risks and weaknesses and ensure that corrective action is taken.

[10] The architecture the contractor proposes for Phase 2 development might be significantly different than the architecture proposed during the Phase 1 study contract.

8 Summary

In this technical note, we discussed the key role of software architecture in enabling the quality of software-intensive systems. We also discussed how software architecture evaluation can reduce risk in a system acquisition by clarifying the architecture's ability to meet quality attribute requirements. We described how QAWs are being used in a major system acquisition to evaluate architectures in a relatively non-intrusive manner, and how they are enabling the acquiring organization to generate and analyze scenarios about a system during the design process. We described the major activities involved in conducting a QAW and how these activities can provide insight into the contractors' progress of architecture development. We also identified workshop results, lessons learned, and acquisition issues that surfaced as a result of developing and facilitating the workshops. Finally, we identified two key downstream opportunities for incorporating a formal architecture evaluation as part of the system acquisition strategy.

Members of the SEI Product Line Systems Program are collaborating with several DoD and government acquisition organizations to explore the appropriate use of QAWs and ATAM evaluations within these organizations. The goal is to help these organizations adopt architecture evaluation practices and to ensure that architecture evaluation becomes an integral part of the acquisition process.

To date, SEI staff members have conducted a handful of QAWs. As experience is gained, we will continue to share our expertise in future technical notes.

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Feedback and Contact

Comments or suggestions about this document or the series of technical notes on architecture evaluation in the DoD are welcome. We want this series to be responsive to the needs of DoD and government personnel. To that end, comments concerning this technical note, the inclusion of other topics, or any other issues or concerns will be of great value in continuing this series. Comments or suggestions should be sent to

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To a large extent, a system's software architecture determines the quality attributes of both the software and the entire system. It is also one of the earliest artifacts available for evaluation. For a Department of Defense (DoD) or government acquisition organization, the ability to evaluate software architectures early in the acquisition cycle can positively affect the delivered system. To assist a government organization in evaluating architectures, a series of Quality Attribute Workshops (QAWs) were planned and an initial set conducted as part of a competitive acquisition of a complex, integrated command and control system. The QAW is a "lightweight" (i.e., non-intrusive) version of the Architecture Tradeoff Analysis Method℠ (ATAM℠) developed by the Software Engineering Institute (SEI).

The technical note provides an overview of the QAW process and the results of the first set of workshops, including the perceived benefits of the workshops to both the acquirer and the contractors. This technical note also discusses future opportunities for applying a full-scale architecture evaluation (e.g., an ATAM evaluation) in early stages of system acquisition, and identifies the benefits that could be obtained.

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